POLESET

"THE BETTER WAY"

Manufactured by

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CHAPTER 1 HISTORY OF POLESET

Poleset was a patented product of Forward Enterprises, Inc. Poleset is a rigid polyurethane foam which had been chemically modified to allow it to be applied in cold region and to be water immiscible. As a vanguard during the late 1960's, Forward Enterprises began to apply Poleset to utility structures such as various types of poles, piling, anchors, Vertical Support Members (VSMs), pipes, ducts, fence posts, etc.

The use of field-cast Poleset foam has gained wide acceptance within portions of the continental United States as an alternative means of backfilling around transmission towers, poles and anchors. Poles and VSM are set in conventionally augered holes and premeasured amounts of liquid Poleset are then poured or injected into the holes. The liquid Poleset immediately begins reaction and expands up to 15 times its original volume and then solidifying. Within ten minutes, the pole or VSM is set and can be released.

In 1974, Poleset was reported to successfully be used to erect 200 poles for Manitoba Hydro at a temperature of -10 degrees with a wind of 40 miles per hour. The compressive strength was over 100 PSI.

The long-term effectiveness of Poleset foam in structural integrity and corrosion-protection for direct-embedment structures has been established not only by Forward Enterprises, but also by E. I. Dupont. Their studies show that partial embedment of foam-faced panels in soil for ten years "showed negligible deterioration of the foam and of the attached metal protected by Poleset."

Forward Enterprises has been setting all types of structures in the ground, from transmission poles to vertical support members in the Arctic cold regions for two decades.

Twenty-five-year application of Poleset in both domestic utility structure and cold region VSM setting has demonstrated the following general advantages using Poleset as backfilling material.

1) *Environment acceptable*
no freon
complies with EPA leachate requirements
prevents wood preservatives from leaching through the foam into the ground
foamed material is inert

2) *Structurally sound*
greater shear bond strength
temperature-independent bond strength
great long-term stability

3). *longer pole's life*
curtails ground line rot/corrosion
maintains wood pole preservative in pole

4). *Fast backfilling*
less time to set
much less transportation of backfilling materials
no freeze-back time
substantial reduction of labor requirements

CHAPTER 2 PROPERTIES OF POLESET

2.1 Physical Properties

Mechanical Properties

Unconfined Compressive Strength	75 psi
Tensile Strength	64 psi
Cohesive Strength	37 psi
Young's Modulus	1500 psi

Thermal Properties

Thermal Conductivity K Factor	.255 (BTU/hr/ft^2 /^{o}F/in) @ 75 °F
Thermal Expansion Coefficient	40x10^{-6} per °F

Service Properties

Temperature, Upper Limit	225-250 °F
Temperature, Lower Limit	-300 °F

Cell Properties

Closed Cells	90% of Volume
Water Vapor, Perm, Perm-in.	1-4
Water Absorption, per sq. ft.	.0516

Electrical Properties

Dielectric Constant 1,000 CPS	1.04
Loss Tangent	.05

2.2 Environmental Specifications of Poleset

Poleset was developed to have excellent environment-compliant properties. They are as follows:

Weather Resistance

Cover or coated	Excellent
Uncovered	Skin Deterioration

Drastic Temperature Change

Bonded	Little Change in Cracking

Chemical Resistance

Water	Excellent
Brine, 10%	Good
Brine, Saturated	Good
Sulfuric Acid, 10%	Good
Sulfuric Acid, Concentrated	Poor
Nitric Acid, Concentrated	Poor
Hydrochloric Acid, 10%	Good
Hydrochloric Acid, Concentrated	Poor
Ammonium Hydroxide, 10%	Good
Ammonium Hydroxide, Concentrated	Fair
Sodium Hydroxide, Concentrated	Good

Solvent Resistance

Most Aliphatic, Alicyclic Hydrocarbons	Good

Fungus Resistance	Excellent

CHAPTER 3 ADVANTAGES OF POLESET USED IN COLD REGIONS

The Army Cold Regions Research and Engineering Laboratories had been authorized to conduct a laboratory testing program to study the feasibility of using Poleset foam to foundation construction and performance in cold region in 1976.

This study indicates that Poleset foam has good potential for use in foundations in permafrost areas, particularly for setting piles and anchors which depend on shear resistance between the foundation and permafrost for their support. This programs nevertheless indicated that:

a. The foaming reaction goes to completion even at cold temperatures as long as the two ingredients are kept near room temperature prior to mixing.

b. The bond to cold steel and frozen soils is excellent. The bond can exceed the shear strength of the foam itself if the steel is clean and roughened slightly and if the soil is striated as would occur on the sides of an augered hole.

c. The foaming reaction is exothermic. The reaction heat was, however, less than that produced in freezing an equal volume of sand-water slurry.

d. The urethane foam is an excellent insulator which would tend to prevent summer heat from passing down through the foundation into the permafrost.

e. Creep rate decays exponentially with time and that long-term creep deflections will be small compared to deflections during loading.

Forward Enterprises' first application of Poleset in cold region was to install oil pipeline's VSMs in the Alaskan permafrost in 1980. Despite extreme severe cold, windy arctic condition, as many as 80 VSMs were set per day by using Poleset. This method was significantly faster than the conventional sand-slurry method of backfilling VSMs in the arctic climates. A number of advantages using Poleset were presented:

First, the entire filling of the hole can be done in one operation. Only seven minutes were required from pumping liquid Poleset into the hole to form a rigid form. The greatly improved efficiency of installation is of tremendous importance in tundra where construction time is limited, weather is extremely severe, and labor is very expensive.

Transporting the Poleset system is much more efficient, primarily due to the fact that the Poleset reacts to form a rigid foam up to 15 times their original volume.

The second principal advantage of Poleset over sand-slurry-fill concerns the matter of pole stability itself. With Poleset, VSMs are quickly and permanently stable because they are completely surrounded by a casing of rigid Poleset foam. Poleset form has an excellent insulation property, so temperature changes in the VSM do not affect the constant temperature of the permafrost, and thus have no effect on it. Poleset, once cured, is a strong, cohesive material which resists moisture and freeze/thaw cycles.

The following analysis has been conducted to investigate how Poleset backfilling will replace a thermopile and eliminate frost heaving effect on pile or anchor structures, otherwise, driven or backfilled with sand-slurry.

Thermopile was conventionally used to reduce the freezeback time or lower the temperature below the active layer in the winter and to maintain a high adfreeze bond strength which is temperature-dependent, between the pile and the surrounding soil or backfilling such as sand-slurry. A thermal device is embedded inside the pile to transfer the heat from the high-temperature ground up to the air.

A driven or sand-slurry backfilled pile is frequently subject to the frost heaving or soil thawing problem and may need a thermopile to maintain low temperature to keep a sufficient adfreeze bond strength which is temperature-dependent. However, a thermopile is not required when using Poleset foam backfilling a pile. The shear bond strength between the pile shaft and the Poleset foam is constant and temperature independent. Nevertheless, the reaction heat of the foaming is insignificant, less than the heat given off by sand-slurry backfilling. Furthermore, Poleset has an excellent insulation property with a thermal conductivity of 0.255, which is 29 times less than that of concrete. This will reduce the heat transfer between the pile and the surrounding soil to a minimum and greatly decrease subsequent soil thawing and subsequent subsidence. Therefore, Poleset backfilling will eliminate the need of using thermopile.

Frost heaving is one of the most challenging problem to a cold-region geotechnical engineer. Frost-heave can cause the jacking of pile foundations, poles, and VSMs. The total amount of heave up to 6 inches in a season is not unusual, this will be sufficient to cause the failure of foundation structures and to prevent the serviceability of a pipeline or facilities. Moreover, the break of the pipeline can result in the leaking of gas and spilling of oil, a severe environment contamination which is extremely costly to remediate.

U.S. Army/Air Force reported that an oil-wax mixture having a thick consistency was attempted to fill the annulus between the pile and casing to isolate heave force in pile foundation. A premixed backfill of soil, oil, and wax was also attempted to reduce frost-heave thrust of a pile. These methods are obvious to be costly and time-consuming.

Various methods of providing additional shear strength in permafrost (including notching the pile, driving railroad spikes in timber, and welding angle-iron flanges to steel piles) have been only partially effective in eliminating frost heaving of lightly loaded piles. Thermopiles offer increased anchorage against frost heaving by lowering of pile surface temperatures in the permafrost during the fall and winter. Self-refrigerating thermopiles reduce the depth of summer thawing and furnish heat to that portion of the pile in contact with the active zone, thereby reducing the adfreeze bond involved in the frost-jacking process. It seems that currently no effective method has been developed to solve frost heaving problem of piling and VSM. But Poleset backfilling offers a innovative approach to eliminate frost heaving, contributed by the following three factors.

(1) No water existence in Poleset

Water is not used in Poleset so that Poleset itself will not subject to frost heaving in the active zone in winter, unlike the presence of water in the sand-water slurry.

(2) Lower elastic modulus

Poleset has a much less (about 50 times or more) shear modulus than any typical frozen sand or silt and 12,000 less times than a steel pile. This implies that most of the frost heaving deformation will be undergone by backfilling foam, instead of the piling or VSM, and the frost-heaving uplift force on the piling or VSM will be significantly reduced by using Poleset.

(3) Temperature-independent bond strength

Sand-slurry backfilled or driven piles produce adfreeze bond strength that is proportional to temperature, therefore, in the winter, lower temperature near the surface in the active layer results in a very high adfreeze strength, severe frost heaving of pile foundation occurs when this strength is larger than the net downward force.

However, the bond strength between Poleset and pile surface is independent of temperature, so the lower temperature in the winter would not cause a high bond strength and it is reasonable to assume that the bond strength of Poleset along the pile shaft is uniformly distributed. Usually, the pile embedment length in permafrost is larger than the thickness of the active layer (at least 2 to 3 times recommended by Tsytovich), therefore, in any season, the bond strength in deep permafrost is larger than that in the active layer, and the pile would not be jacked up by the surrounding frost heaving.

The above analysis show that Poleset backfilling VSM or piling offers an unique advantage to eliminate frost heaving on the pile foundation, transmission line poles, and VSMs for pipeline in the permafrost.

Creep Behavior The laboratory study showed that Poleset's creep rate decays exponentially with time and that long-term creep deflection is small compared to the deflection during loading. The strain at 30 years would only be 1.75 times that at 0.5 minute. This indicated that Poleset is excellent to resist creep deformation.

Conclusions In comparison to both sand-slurry and pile driving methods, Poleset backfilling not only provides a reasonable temperature-independent bond strength and a long term behavior with a negligible creep effect, but also shows an exceptional feature of eliminating the need of thermopile and frost heaving, and greatly reducing the subsequent soil thawing, subsidence problems to a minimum.

The foregoing conclusions are further substantiated by 15 year service performance in varied arctic environments.

CHAPTER 4 COMPARISON OF POLESET FOAM BACKFILLING VERSUS SAND-SLURRY BACKFILLING AND PILE DRIVING METHODS

Conventionally, pile driving and sand-slurry backfilling methods are two of the primary methods to install pile foundations in the arctic permafrost region. These two methods are compared with the Poleset foam backfilling in the following.

4.1 Poleset Versus Sand-slurry Backfilling Method

The detailed comparison of Poleset and sand-slurry backfilling method is made and summarized in the following Table 1.

4.1.1 Overall Comparison

Table 1 Poleset Versus Sand-Slurry Backfilling Method on the Ardalin Pipeline Project.

Item	Sand/Water Slurry	Poleset Foam
Pours & Set Times		
8-inch diameter	1 pour & 12 hours	1 pour & 15 minutes
14-inch diameter	2 pours & 36 hours	1 pour & 15 minutes
Crew	4 personnel at plant	1 person
	6 personnel on trucks	
Progress per crew per 10-hr shift	20 VSMs	65 VSMs
Time to set 5000 VSM @ two 10-hr shifts per day	250 shifts (125 days)	77 shifts (39 days)
Advantages/ Disadvantages	Wedging/jacks needed until freeze-back	Wedging/jacks can be removed in 15 minutes
	10 personnel needed for 4 mo.	1 personnel needed for 1.3 mo.
	2 stages needed for 14 in. sand & water locating	1 stage for all VSM
	Permitting & hauling downtime of plant unknown	
	Propane availability unknown	
Design Comments	Tundra damage effect on VSM design unknown	Less concern for tundra damage
	Heat transfer to Permafrost 2 times greater than Poleset	
	Sand spec. availability assumed	

The above comparisons show that Poleset foam backfilling is three-time faster than sand-slurry method, and it needs less crew and less equipment and less material transportation. Poleset backfilling is more efficient, simpler, and versatile method.

4.1.2 Heat Transfer

1) Sand-Slurry

In a typical installation, pile diameter = 1.5 ft., Hole diameter = 2 ft., Hole depth = 20 ft.

The space of annulus:

$V = \pi \times (R^2 - r^2) \times D$

$V = \pi \times (1^2 - .75^2) \times 20$

$V = \pi \times (1 - 0.5625) \times 20 = 27.5\ ft^3$

Thermal piles are usually used with sand-slurry methods, the inside of the pile is also filled with sand-slurry to embed thermal device. Hence, the volume of sand-slurry is the following:

$V = \pi R^2 D = \pi \times 1 \times 20 = 62.8$ ft.^{3}

Backfill consists of sand saturated with H_2O, in which typical water content is 15%. Sand-slurry mix will be presented to the hole at 40°F. Heat transfer will cease when the mix reaches the temperature of the permafrost = 17°F.

Heat lost from the sand as temperature drops from 40°F to 17°F. (ΔT = 23°F).
Density of sand = 100 lb/ft^3
Specific heat of sand = .191 BTU/LB -^{o}F.

85% x 62.8 ft^3 x 100 lb/ ft^3 x .191 BTU(lb °F) x (23°F) = 23,450 BTU

Heat loss from H_2O as temperature drops from 40°F to 32°F. (ΔT = 8°F).
Density of H_2O = 62.4 lb/ft^3
Specific heat of H_2O = 1.0 BTU/LB - ^{o}F.

15% x 62.8 ft.^{3} x 100 lb/ft^3 x 1.0 BTU(LB °F) x 8°F = 7,536 BTU

Heat loss to freeze H_2O
Lb. of H_2O present 62.8 x 0.15 x 100 = 942 lb
Latent heat of fusion of H_2O = 144 BTU/LB

942 lb x 144 BTU/LB = 135,648 BTU

Heat loss from ice as temperature drops from 32°F to 17°F. (ΔT = 15°F).
Specific heat of ice = 0.5 BTU/LB - ^{o}F.

942 lb x 0.5 BTU/LB x 15°F = 7065 BTU

Total heat transferred to permafrost and pile = 23,450 + 7,536 + 135,648 + 7065 = 173,699 BTU

Without using thermopile, total heat transferred to permafrost and pile
= 173,699 x 27.5 / 62.8 = 76,062 BTU

2) Poleset

Backfilling material consists of a Poleset foam that occupies 100% of the annular void.
Foam density (down hole) = 7 lb/ft^3

Weight of Poleset per piling = 27.5 ft^3 x 7 lb/ft^3 = 192.5 lb.

Total heat to be dissipated to permafrost, pile and air is equal to the heat added to the liquid components to raise their temperature from 17°F to 85°F (the temperature of the Poleset during dispensing process), plus the exothermic heat of the reaction.

Heat added to the liquid components to raise the temperature from 17°F to 85°F (T = 68°F)

Average specific heat of two components = .14 BTU/lb - ^{o}F

192.5 lb x .14 BTU/lb -^{o}F x 68°F = 1832 BTU

Exothermic heat of reaction:

Exothermic = 25 Kcal/gm mole
1 gm mole = 250 grams
Poleset weight = 192.5 lb.

192.5 lb x 453.6 gm/lb x gm mole/250 gm x 25 Kcal/ gm mole x 3.97 BTU/Kcal = 34665 BTU

Total heat to be dissipated to the permafrost and pile and air = 1,832 + 34665 = 36497 BTU.

3) Heat Transfer Comparison

Heat produced during backfilling:

Sand slurry mix = 173,699 BTU
Sand slurry mix = 76,062 BTU (without thermopile)
Poleset = 36,497 BTU

Notes:

1. It is expected that heat transfer takes place at the rate of 33 BTU/hr - ft^2
   Thermal conductivity of standard Poleset is 0.255 BTU/(hr)(ft^2) (^{o}F/in)
   The heat should be dissipated within 10 hours. More heat is expected to dissipate to the air through steel pile surface in higher temperature Poleset foam than in lower-temperature sand-slurry.
2. The calculated heat of 36,497 BTU for Poleset is a maximum number. It is expected that actual installations to develop a lesser amount of heat.

4.1.3 Summary

It is concluded that the Poleset foam develops 2 to 5 times less heat than sand-slurry to backfill a pile or thermopile, in addition, more heat in the Poleset foam will be dissipated to the air through cold steel pipe pile surface, therefore, less heat for Poleset is transferred to permafrost and causes less disturbance on tundra than sand-slurry.

4.2 Poleset Foam Backfilling Versus Pile Driving Methods

Conventional pile driving without a pilot hole is a relatively simple, direct pile-installation method, but it is not always possible to drive a pile into permafrost, particularly in the hard ground with a low temperature permafrost, hence, an improved pile driving has been developed with a predrilled pilot hole to reduce the driving resistance and better control the driving and embedment depth. This method has gained popularity in the North Slopes and Russia. A relatively new Poleset foam backfilling pile foundation or VSM has been successfully used in the cold region. The merits of these methods are compared in the context.

Poleset foam is virtually applicable to all types of ground conditions as long as a pile hole can be drilled and maintained for a few minutes. But the use of pile driving is limited by the equipment capacity and performance, soil and weather conditions, temperature, etc. Favorable conditions for pile driving are where the soils are fine grained, the ice content of the soil is low, and the temperature of the permafrost is high and the presence of significant groundwater (however, these are not optimum conditions for adfreeze strengths). A pile cannot be driven in frozen gravels and cobbles without the use of a pilot hole. Vibratory driving are particularly good in fine-grained saturated thawed soils or weak frozen soils, such as those produced by the thermally modified pilot hole method. Vibratory hammers have been used for slow driving in warm frozen silts without the use of pilot holes. Vibratory hammers may have difficulty driving piles into cold dense frozen soils or where there is a predominance of coarse gravels and cobbles.

Table 2 summarizes the selection of pile installation methods under different conditions, including sand-slurry method.

4.2.1 Ground Conditions

Table 2 indicates that Poleset foam backfilling is more adaptive to different ground conditions than pile driving and sand-slurry method.

Table 2 Matrix of Pile Installation Methods versus Design Conditions

Pile Installation Methods	Ground water	Saturated Thawed Soils	Intermittent permafrost and soils	Rock or Boulders	Most Frozen Soils	Very Dense Gravels	Offshore
Pile Driving	x	x	x		x	x	x
Poleset foam	x*	x	x	x	x	x	
Sand Slurry				x	x	x	

Note: * indicates the application in large inflow rate is limited to some extent.

4.2.2 Equipment and Manpower

Table 3 and 4 summarize the equipment and manpower requirements for pile driving method and Poleset foam backfilling method, respectively.

Table 3 Equipment and Manpower Requirements for Pile Driving Method.

Function	Equipment	Manpower
Survey	Truck	1 Party Chief 2 Instrument men
Pilot Hole Drilling	Drill	1 Driller and 1 Laborer
Pile Stringing	Front-End Loader	1 Operator
Pile Driving	Driving Hammer Crane Generators Boiler Truck Welding Truck	1 Crane Operator 1 Crane Oil/Operator 1 Boiler Truck Operator/Driver 1 Hammer Operator 1 Laborer Foreman-Coordinating Driving Activities 2 Laborer Riggers 1 Welder 1 Welder Helper 1 Inspector-Observe Installation and Record Data
		1 Pipefitter Foreman-Responsible for

Cross Beam Bolt-up	Front-End Loader	Alignment of Piles Before Driving, Bolt-up of Beams After Driving 2 Helpers Assist Pipefitters
Management	3 Pickup Trucks	Superintendent Project Engineer Field Engineer Time Keeper/Secretary

Note: 1. At least one full-time mechanic is required on the job at all times.
2. Fuel and lube truck required twice daily for double shift operations.
3. Light plants required for winter and night work.
4. Equipment and manpower requirements for snow removal operations not included.
5. Water is placed in pilot hole 40 - 60 minutes prior to pile driving.

Table 4 Equipment and Manpower Requirements for Poleset Foam Backfilling Method.

Function	Equipment	Manpower
Survey	Truck	1 Party Chief 2 Instrument men
Drill Pile Hole	Drill	1 Drill Operator 1 Laborer 1 Oiler/Driver
Pile String, Bolt and Set-up	Crane	1 Crane Operator-to set pile 2-3 labor assist
Permanent Pile Installation	Poleset Dispensing Machine	1 Machine Operator
Management	1 Pickup truck	Superintendent or Engineer

The above comparison of pile driving and Poleset foam backfilling methods shows that pile driving method requires much more equipment and labor than Poleset foam backfilling method, and the latter is simpler to operate.

4.2.3 Production rates

Table 5 shows that Poleset foam backfilling has a 2-3 times faster installation rates than driving methods, while vibratory and sonic hammer (rarely used) are more effective than impact hammer driving.

Table 5 Pile Installation Rate Per Rig (10-hr. Shift)

Driving conditions	Poleset Backfilling	Impact Hammer	Vibratory Hammer	Sonic Hammer
Easy	60-80*	20-25	30-40	Similar to Vibratory Hammer
Medium	50-60*	15-20	15-20	
Hard	40-50*	6-8	0-5	

Note: Driving crew size: Operator, oiler, foreman, 3 journeymen, 10-hour work day for normal summer conditions for 20-ft pile.
* indicates that the rate of Poleset backfilling depends on the rate of pile hole drilling excavation and pile setup, injecting Poleset and foaming only takes a few minutes.

4.2.4 Weather Effect

Table 6. Effect of Weather on Pile Driving

Temperature °F or conditions	Pile Installation Results	Efficiency Factor
50	Excellent	100
32 to 50	Very good to Excellent	90 to 100
-4 to 32	Good	60 to 90
-20 to -4	Fair to Good	40 to 60
-40 to -20	Poor to Fair	20 to 40
-60 to -40	Poor	0 to 20
Rain		Little effect
Snow		Light -- 10% loss
		Medium -- 20% loss
		Hard -- 50% loss
Wind		0 to 20 -- little effect
		20 to 30 -- 10% loss
		30 to 50 -- 50% loss
		50+ -- 100% loss

Note: Heat loss in cold weather increases logarithmically when combined with wind chill factor. All diesel or hydraulic hammers require heat to work efficiently and operate best above 40 ^{o}F. Electric vibratory hammers tend to work better in cold environments.

It is seen from the above table that in comparison to the Poleset foam backfilling, which requires less equipment, the pile driving is increasingly subject to the change in the weather conditions and makes the construction schedule difficult to predict. The severe conditions increases the cost of pile driving unexpectedly. But Poleset foam backfilling is little affected by the weather conditions as long as a pile-hole driller is operable.

4.2.5 Parametric Comparisons

The following factors are examined in comparison to these pile installation methods one another.

Freezeback Time Pile driving method with a predrilled pilot hole takes 2 days of freezeback time in 23 ^{o}F or 1 day in 20 ^{o}F permafrost. This is longer than Poleset foam backfilling, which requires a few minutes to become rigid. The water temperature of 59-80 ^{o}F and 149-212 °F are required for the pilot hole in warmer and cold permafrosts, respectively**.**

Structural Strength Structural strength of a driven pile for most load applications is achieved after freezeback time because the pilot hole water disturbs the tundra. Poleset backfilling gains a known strength immediately after foaming and reaches the maximum strength within 24 hours. The effect of dynamic driving on the adfreeze strength and creep deformation has not yet been studied.

Heat Transfer Poleset produces the chemical exothermic reaction and the heat is partially transferred to the permafrost; pile driving produces the mechanical and frictional heat during driving and the heat from the hot water used for drilling a pilot hole. Exothermic heat in Poleset backfilling is less than in sand slurry. A field investigation of pile driving by Vyalov in 1966 reported that the temperature of the soil adjacent to the pile had increased to about 50° - 59°F from initial value of 30 °F, not counting the heat produced by the hot water used in drilling a pilot hole.

Installation Accuracy Conventional direct driving is frequently not able to drive a pile to a designed depth due to the variation of soil conditions. Although the pilot hole driving method is more controllable than the conventional direct driving method, less installation accuracy for driven piles is expected over Poleset foam backfilling method**.**

Field Welding The field welding of driven piles to the steel cap plates is needed due to the less precise placement tolerances. The welding can be done in the shop for Poleset foam backfilling method.

Load Capacity Poleset foam develops a known shear bond strength along the pile-foam interface. The shaft resistances for driven piles are variable according to the soil, pile surface, installation methods. In the unfrozen soil, the load capacity can be predicted according to the driving data such as the blow count per inch penetration through decades of studies and experiences. However, in frozen soil, such a relationship between the driving resistance and load bearing capacity needs to be developed. Furthermore, the limited number of soil boring are often not sufficient to clearly describe the soil conditions, and the number of pile load tests are also limited, even not available. All these factors complicate and challenge the designer. Therefore, a innovative design using Poleset backfilling VSMs or pile foundations with a constant bond strength regardless of the soil conditions will significantly enhance the geotechnical engineer's confidence in the design, greatly simplify it and improve its reliability with reduced unknown soil conditions**.**

Installation Stress The significant dynamic stress is induced during driving, especially for impact driving, less for vibratory driving. Pile cap and pile tip are needed to be reinforced to avoid the failure during driving. The driving method is not proper for timber pile, specially reinforced pile head and toe are needed for concrete pile, sometimes the failure is induced in steel pipe pile driving. But with a predrilled pile hole, any type of piles using Poleset foam backfilling method are free of installation stress.

Pile Type Due to the limitation of the driving resistance, a closed-ended pipe pile is generally not used for the driving method, although it develops a higher bearing capacity. Poleset foam backfilling is regardless of pile type, even though a H pile consumes more Poleset**.**

Corrosion or Rot Protection Poleset foam backfilling with a closed cell content of 95%+ virtually keep the water and other hazardous fluid or gas from the pile surface, this effectively curtails the corrosion of a steel pile and rot of a timber pile.

Frost Heaving In the following winter after a pile was driven, the frozen active layer will be frost heaving and build up a very high adfreeze strength on the driven pile and cause the pile to jack up, a significant upward movement of the pile will be sufficient to destroy the integrity of the foundation and structures.

Frost heaving can be avoided by using Poleset foam backfilling a pile foundation since the jackup force built on the pile by frost-heaving action will not be temperature-dependent and never be larger than the downward bond strength in winter**.**

Thermopile Thermopile is widely used in the warm temperature permafrost to reduce the freezeback time and to keep a lower temperature around the pile.

However, thermopile is not required when using Poleset foam backfilling a pile. The reason is that shear bond strength between the pile shaft and the foam is constant and temperature independent. Nevertheless, the reaction heat of the foaming is insignificant, less than the heat given off by sand-slurry backfilling. Furthermore, Poleset has an excellent insulation properties with a thermal conductivity of 0.255 BTU/(hr)(ft^2) (^{o}f/in), which is 29 times less than that of concrete. This will reduce the heat transfer between the pile and the surrounding soil to a minimum and greatly eliminate subsequent soil thawing and subsequent subsidence.

Creep Behavior The laboratory study showed that Poleset's creep rate decays exponentially with time and that long-term creep deflection is small compared to the deflection during loading. The strain at 30 years would only be 1.75 times that at 0.5 minute, appreciably smaller than the creep rate of ice. This indicated that Poleset is excellent to resist creep deformation.

4.2.6 Conclusions

In comparison to pile driving method, Poleset foam backfilling exhibits number of advantages: about two to three times faster installation rate, requirement of smaller crew, less field equipment, no field welding, no freeze-back time; adaptive to any type of piles; no installation stress induced; immediately able to accept loading; excellent corrosion or rot protection for steel and timber piles; a pile can be accurately installed at a designed depth; the design is simplified with a significantly improved reliability of bearing capacity prediction.

While a driven pile is subject to the frost heaving problem and may need a thermopile, Poleset backfilling provides not only a reasonable temperature-independent bond strength and a long term behavior with a negligible creep effect, but also shows a exceptional feature of eliminating the need of thermopile and reducing frost heaving, soil thawing, subsidence problems to a minimum.

CHAPTER 5 CASE HISTORIES

Poleset has been applied in the following primary projects in both cold regions and continental United States to the date of April, 1993.

Table 7. List of Poleset Applications.

Company	Structure	Location	Length (miles)	Year	Permafrost Temperature
ARCO	Pipeline VSM	Prudhoe Bay, Alaska	13.6	1979	10°F
ARCO	Conductor Pipe	Prudhoe Bay-Kuparak, Alaska		1981	10°F
ARCO	Pipeline VSM	Kuparak, Alaska	16	1981	10°F
ARCO	Transmission Line	Kuparak, Alaska	14	1981	10°F
CONOCO	Pipeline VSM	Milne Point, Alaska	16	1984	10°F
CONOCO	Pipeline VSM	Polar Light, Russia	40	1992 - 1993	30°F
Utilities Co.	Transmission	Lower 48 States	1335	1969 -	x

				1993	
Utilities Co.	Distribution	Lower 48 States	5050	1969 - 1993	x

CHAPTER 6 POLESET TESTS

6.1 Quality Assurance

Prior to taking the dispensing machine to the job site, a sample should be made and tested according to ASTM Standard.

The Poleset supplied for setting vertical support members (VSMs) shall have free-rise:

Density ....5.5 lbs/cu.ft. ± 5%
Compressive Strength ....75 psi minimum

6.2 Bond Strength Test

The most pertinent test performed in our laboratory for vertical support members is the bond strength of the Poleset to steel pipe VSM.

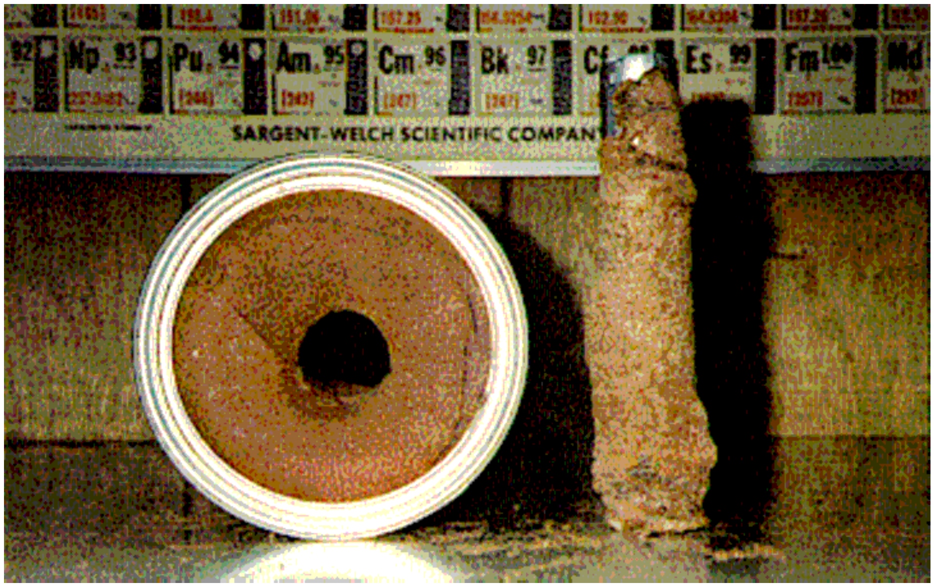
Test Procedures

Due to non-existence of an established test procedure for bond-strength, Forward Enterprises developed the following procedure:

1 - Obtain sample from reactor batch of components "A" & "B".
2 - Raise temperature of components to:
    "A" - 95°F
    "B" - 85°F
3 - Use a 1.6 in dia. schedule 40 pipe and a 6 in. dia. metal container.
4 - Place pipe & container in 0°F freezer for 24 hours period, minimum.
5 - Mix components - Pour - set pipe - put test specimen into freezer for 24 hours.
6. Retrieve specimen, remove bottom of container.
7. The specimen pipe is vertically loaded until failure occurs.

Results

The shear bond strength between the pile and Poleset foam was 50 psi in average over 100 laboratory tests. The Poleset samples after testing are shown in the following pictures.



Picture No.1 Sample of specimen after failure. Note that Poleset has bonded to the pipe. This is representative and proves that bond strength is greater than shear strength of Poleset foam itself.

Picture No.2 Sample of specimen that shows shear strength being exceeded. Note that mid-length diagonal lines indicated a shear failure. Also, Poleset foam is bonded to pipe.

6.3 Poleset Tests in Cold Temperature

The following testing procedures were designed to examine the quality of Poleset that are intended to be used in permafrost region.

<u>TEST A</u>

Temperature A & B 95°F

Container & pipe	0°F to 20°F for 12 hours
Compressive strength	65 psi
Cured 16 hours at	0°F
Shear strength (7 tests)	29 psi

TEST B

Temperature A & B	95°F
Container & pipe	0°F to 20°F for 12 hours
Compressive strength	84 psi
Cured 16 hours at	0°F
Shear strength (6 tests)	39 psi

TEST C

Temperature A & B	95°F
Container & pipe	0°F to 20°F for 12 hours
Compressive strength	84 psi
Cured 16 hours at	78°F
Shear strength (6 tests)	53 psi

TEST D

Temperature A & B	95°F
Container & pipe	78°F
Compressive strength	84 psi
Cured 16 hours at	78°F
Shear strength (6 tests)	50 psi

TEST E

Temperature A & B	78°F
Container & pipe	78°F
Compressive strength	84 psi
Cured 14 hours at	78°F
Shear strength (5 tests)	63 psi

The independent party, Polyhedron Laboratory, was also invited to conduct these tests. The test results are summarized in Table 8.

Table 8. Summary of Bond Strength Tests.

	Test A	Test B	Test C	Test D	Test E	Polyhedron Lab
Sample material Compressive strength	65 psi	84 psi	84 psi	84 psi	84 psi	75 psi

Component "A" Temperature	95°F	95°F	95°F	95°F	78°F	78°F
Component "B" Temperature	95°F	95°F	95°F	95°F	78°F	78°F
Container Temperature	0°F to 20°F	0°F to 20°F	0°F to 20°F	78°F	78°F	----
Pipe Temperature	0°F to 20°F	0°F to 20°F	0°F to 20°F	78°F	78°F	----
Ambient Temperature	78°F	78°F	78°F	78°F	78°F	78°F
Cure Temperature	0°F	0°F	78°F	78°F	78°F	78°F
Cure Time	16 hr.	16 hr.	16 hr.	16 hr.	14 hr.	24 hr.
Resultant Shear strength	29 psi	39 psi	53 psi	50 psi	63 psi	37 psi
Number of tests	7	6	6	6	5	6

CHAPTER 7 APPLICATION SPECIFICATIONS

7.1 Application Criteria

The proper application of Poleset will insure that the installation of Vertical Support Members (VSMs) will remain permanent.

Criteria for the proper application of Poleset:

1) VSMs must be free of any foreign material that will affect the bonding characteristics of Poleset (oil, grease, excessive rust or ice).

2) The VSM must be placed in the center of the hole and held in place by blocking or some other means.

3) Once the VSM is at the desired elevation the Poleset may be dispensed.

4) Do not move the VSM for 15 minutes after Poleset has been dispensed and expansion is complete.

Suggestions:

1) It is preferable that the bottom of the VSMs be plugged or covered. If neither procedure of closing up the bottom end of the VSM is used, then the VSM must be driven into the ground or 6 - 12 in of the spoils be put back in the void, this will prevent the Poleset from rising up inside the VSM, which results in excess Poleset being used.

2) The diameter of the holes to be drilled for VSMs should not be any larger than 6 in greater than the outside diameter of the VSM.

3) Holes should be as straight as possible and not overdrilled in diameter or depth. Overdrilling will cause excessive use of Poleset.

7.2 Installation Procedure

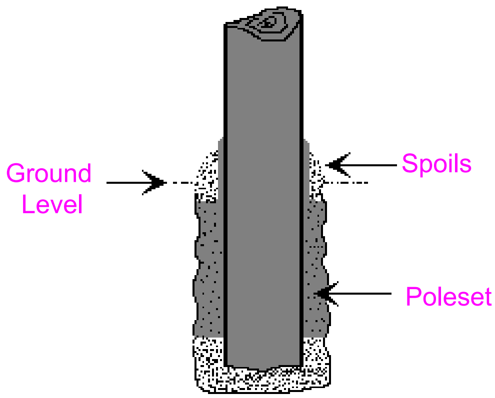
Proper installation of Poleset will assure that the advantages of Poleset will be realized.

After the hole has been dug and a pile or pole is held in place, throw in some spoils to keep foam away from butt of pole for grounding purposes, usually 3 - 6 in.

One of the advantages of Poleset is to help curtail groundline rot on wood poles and groundline corrosion on steel poles.

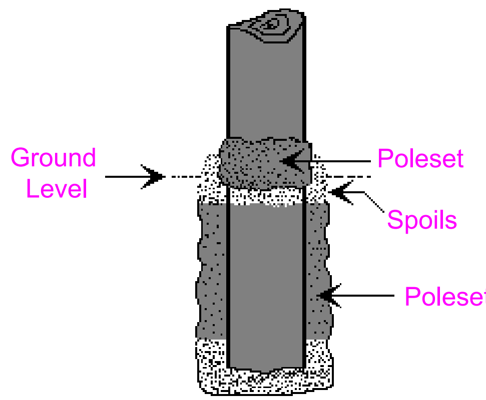
Have the proper size kit close to the hole. Mix the A and B in accordance with the mixing instructions and pour Poleset on pole about 6 - 12 in above the groundline, walking around the pole while pouring.

Pour the remaining Poleset down the annulus, walking around the pole while pouring. The "foamed" material should come up to within 6 in of groundline and blend with Poleset poured on the pole.



CORRECT

Proper pouring gives groundline protection



INCORRECT

Improper pouring exposes pole to groundline rot and corrosion.

7.3 Alternative Installation Procedures

Poleset was developed for use in wet soil conditions and a small amount of standing water in the hole. The standing water should not exceed 6" with the structure in the hole.

The two alternatives are:

1) Pumping
2) Casing

Before detailing the alternatives, the following is an explanation of the process of using polyurethane foam in a hole with more than 6" of standing water.

Poleset enters the annulus in the liquid state. Since it is heavier than water, it sinks to the bottom of the water. Once the chemical reaction (gel) begins, the foam then becomes less dense (lighter) than water, and floats to the surface. As it expands, the foam takes the path of least resistance and rises, leaving the water at the bottom of the hole. Typically in situations where there is 15 cm or less of standing water (with the structure in place), there should be no problem.

ALTERNATIVE 1 -- PUMPING

Pumping is the fastest, simplest and most economical method of preparing the hole for the setting of the structure using Poleset. A vacuum pump or a centrifugal pump, with sufficient lift and capacity, can be used.

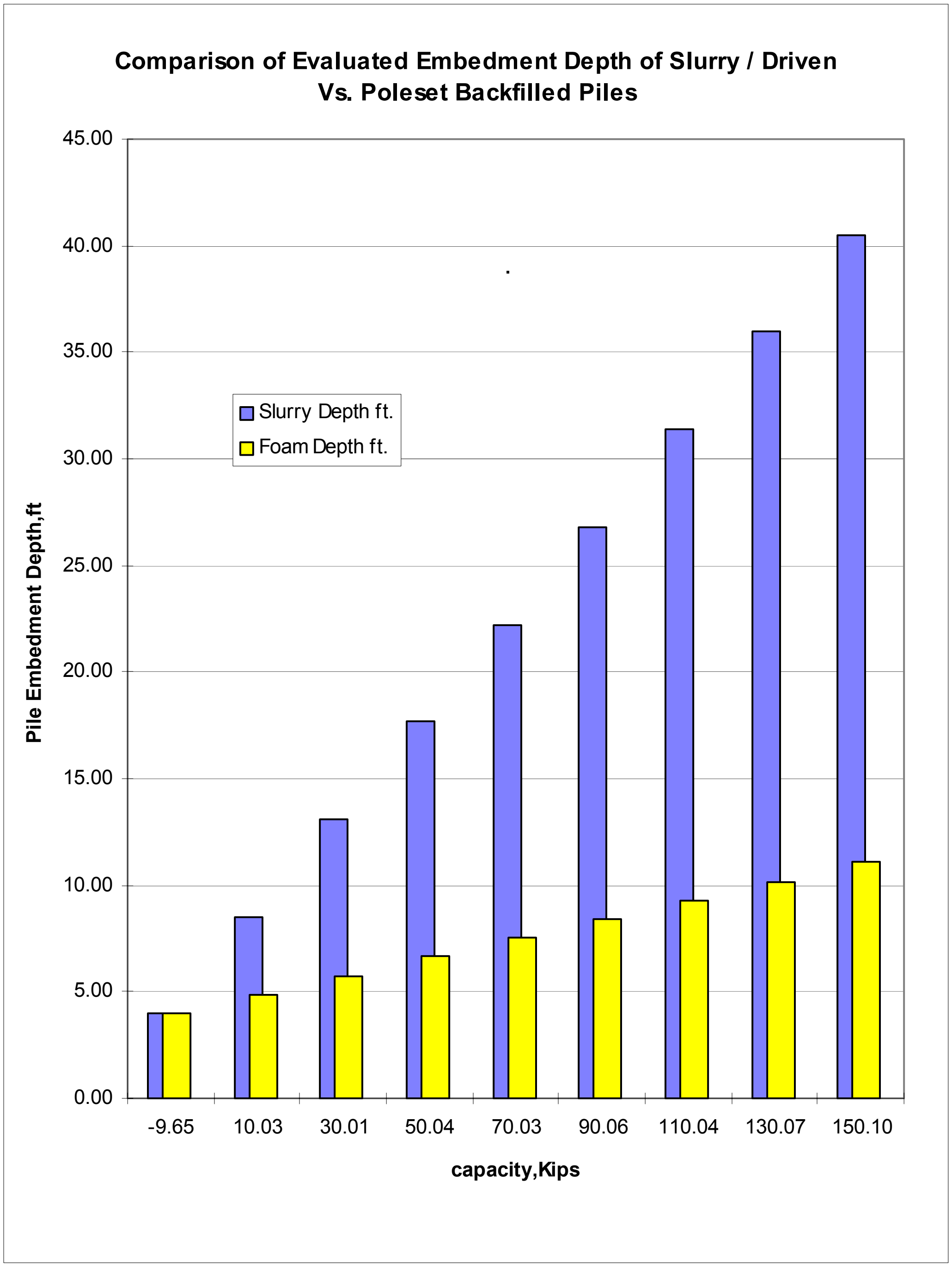
ALTERNATIVE 2 -- CASING

There are situations where, while drilling the hole, there is so much water in the ground that the hole either caves in, or continually fills up with water. The alternative of casing the hole has worked successfully in the past.

Use a corrugated casing of a slightly larger diameter than the auger. The corrugations will result in a higher skin friction (uplift or compression resistance) than a smooth-sided casing.

The casing can be pushed or screwed into the ground to a depth that will shut off water seepage. A simple modification to the casing and tool can be used by adapting a Kelly bar.

Once the corrugated casing is in place, the structure can be foamed in.



Permafrost Temp °F	31	Pile Dia. in.	16
Active Layer ft.	4	Hole Dia. in.	22
Adfreeze Slurry psi	7.25	Downward Shear psi	4
Adfreeze Poleset psi	37.5		

An preliminary estimation of the embedment depth for a sand slurry / driven pile and a Poleset foam backfilled pile.

Sand Slurry backfill

Permafrost Temp °F.	31	Pile Dia.in	16	Hole Dia.in	22
Active Layer ft.	4	Downward Shear psi	4		
Adfreeze Slurry psi	7.25	Adfreeze Poleset psi	37.5		

Embedment Depth from ft.	to ft.	Temp. °F	Adfreeze strength KN/M²	Adfreeze strength psi	A area inch2/inch	L depth ft.	P kip	Cumulative Capacity kip
0.00	4.00	31	-27.58	-4.00	50.27	4.00	-9.65	-9.65
4.00	8.50	31	49.99	7.25	50.27	4.50	19.68	10.03
8.50	13.07	31	49.99	7.25	50.27	4.57	19.99	30.01
13.07	17.65	31	49.99	7.25	50.27	4.58	20.03	50.04
17.65	22.22	31	49.99	7.25	50.27	4.57	19.99	70.03
22.22	26.80	31	49.99	7.25	50.27	4.58	20.03	90.06
26.80	31.37	31	49.99	7.25	50.27	4.57	19.99	110.04
31.37	35.95	31	49.99	7.25	50.27	4.58	20.03	130.07
35.95	40.53	31	49.99	7.25	50.27	4.58	20.03	150.10

Poleset Foam

Embedment depth from ft.	to ft.	Temp. °F	Adfreeze strength KN/M²	Adfreeze strength psi	A area inch2/inch	L depth ft.	P kip	Cumulative Capacity kip
0.00	4.00	31	-27.58	-4.00	50.27	4.00	-9.65	-9.65
4.00	4.87	31	258.56	37.50	50.27	0.87	19.68	10.03
4.87	5.75	31	258.56	37.50	50.27	0.88	19.98	30.01
5.75	6.64	31	258.56	37.50	50.27	0.89	20.03	50.04
6.64	7.52	31	258.56	37.50	50.27	0.88	19.98	70.03
7.52	8.41	31	258.56	37.50	50.27	0.89	20.03	90.06
8.41	9.29	31	258.56	37.50	50.27	0.88	19.98	110.04
9.29	10.18	31	258.56	37.50	50.27	0.89	20.03	130.07
10.18	11.07	31	258.56	37.50	50.27	0.89	20.03	150.10

It is noted that this calculation is based on the above assumed summer permafrost temperature, profile and the adfreeze strength is also assumed for ice-rich soil.
This is only an example to establish the relationship between the embedment depth and loading capacity.